

MEASURING DEVICE FOR A MOTOR VEHICLE

Description

The present invention relates to a measuring device, in particular a measuring device for a motor vehicle, for measuring a distance between the measuring device and at least one object and/or for measuring a speed difference between the measuring device and the at least one object, the measuring device having an emitting device for sending a transmission signal, which includes at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions, the at least two signal portions of a signal portion sequence differing in their frequency in each case by one differential frequency.

Such a measuring device developed as a radar device is known from DE 100 50 278 A1 or from the dissertation by M.-M. Meinecke "Regarding Optimized Transmission Signal Design for Automobile Radars", Technical University Hamburg-Harburg, 2001. Thus DE 100 50 278 A1 discloses the determination of a distance and of a relative speed of at least one distant object from an observation point with the aid of electromagnetic signals emitted from the observation point in the form of alternately emitted signal portions of a first frequency and of a second frequency, which following a reflection by the object are received and evaluated, the signal portions of the two frequencies being emitted during a measuring interval such that they are shifted in each case by one constant frequency increment.

The use of a radar device in the automotive sector is also known from the dissertation "Radar Systems for the Automatic

"Distance Control in Automobiles" by R. Mende, Technical University Carolo-Wilhelmina, Braunschweig, 1999, as well as from DE 199 22 411 A1, DE 42 44 608 C2 and DE 100 25 844 A1.

5 DE 199 22 411 A1 discloses a CW radar method (continues wave radar method) for measuring distances and relative speeds between a vehicle and one or several obstacles, in which a transmission signal is made up of at least four consecutive blocks having in each case different gradients. In a
10 distance-relative speed diagram, first the intersections of all straight lines from two blocks of all discovered frequency positions are calculated. For validating these intersections, they are checked as to whether in the Fourier spectrum of a third block there exists a peak at a frequency position, whose
15 associated straight line in the distance-relative speed diagram intersects a surrounding region of the intersection. The intersections validated in this manner are subjected to a second condition, whether in the Fourier spectrum of a fourth block there exists a peak at a frequency position, whose
20 associated straight line in the distance-relative speed diagram intersects a surrounding region of the intersection. The intersections are regarded as valid if they satisfy both conditions.

25 DE 42 44 608 C2 discloses a radar method for measuring distances and relative speeds between a vehicle and obstacles in front of it, comprising an emission of continuous transmission signals, simultaneous reception of signals reflected by the obstacles during the emission of the
30 continuous transmission signals, mixing of the reflected signals with the continuous transmission signals for obtaining inphase and quadrature signals and processing of these signals into output signals for the distances and relative speeds of the obstacles, the continuous transmission signals being
35 broken down into constant frequency increments of constant

time duration without time interval with respect to each other
and at each constant frequency increment of the reflected
received signal a complex sampling value being recorded and
mixed with the transmission signal of the same constant
5 frequency increment.

DE 100 25 844 A1 discloses an incrementally linear frequency-modulated transmission signal, at least two incrementally linear frequency-modulated ramps being mutually interwoven.
10 Characteristic in this regard is the fact that these two or more ramps have a constant frequency shift with respect to one another. By frequency measurement and phase difference measurement it is possible to calculate unambiguously the distance of the object and the speed of the object from the
15 received signals.

In addition it is known from DE 43 31 440 A1 to form for the radar device I/Q signal pairs for the signal evaluation, a phase shifter being connected between a radar antenna and a
20 radar front end, an evaluation circuit having two signal channels on the input side, the radar front end being connectable via a channel switch to one of the two signal channels, the phase shifter and the channel switch being clocked synchronously and the phase shifter switching the
25 phase between 0° and 45° with each clock cycle.

A Doppler radar device for a vehicle for indicating a distance between the vehicle and an obstacle is known from
DE 689 13 423 T2.
30

It is the objective of the present invention to indicate a measuring device having an improved measuring accuracy as compared to DE 100 50 278 A1. For this purpose it is desirable, with the aid of the measuring device, to keep the
35 occurrence of so-called ghost targets low or to eliminate it

entirely, to allow for a measuring time of less than 10ms and to allow for the detection of objects at a very close range (0m ... 1m) as well as at a medium and remote range.

5 The above-mentioned objective is achieved by a measuring device, in particular a measuring device for a motor vehicle, for measuring a distance between the measuring device and at least one object and/or for measuring a speed difference between the measuring device and the at least one object, the

10 measuring device having an emitting device for sending a transmission signal, which includes at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions, at least two signal

15 portions of a signal portion sequence differing in their frequency in each case by one differential frequency, the differential frequency of the first signal portion sequence differing from the differential frequency of the second signal portion sequence, in particular by at least 5%, advantageously

20 by at least 10%.

In an advantageous refinement of the present invention, the measuring device has a receiving device for receiving a reflection signal of the transmission signal reflected by the

25 at least one object and advantageously a mixer for mixing the first signal portion sequence with a portion of the first signal portion sequence reflected by the at least one object to form a first mixed signal. In a further advantageous refinement of the present invention, the measuring device

30 additionally has an evaluation device for ascertaining the frequency or frequencies of the first mixed signal. The evaluation may occur with the aid of an FFT (fast Fourier transform), for example.

In another advantageous refinement of the present invention,
the evaluation device allows for the distance between the
measuring device and the at least one object and/or the speed
difference between the measuring device and the at least one
5 object to be determined as a function of the measured
frequencies of the first mixed signal.

In another advantageous refinement of the present invention,
the mixer allows for the second signal portion sequence to be
10 mixed with a portion of the second signal portion sequence
reflected by the at least one object to form a second mixed
signal, and the evaluation device allows for the measured
frequencies of the second mixed signal to be ascertained.

15 In another advantageous refinement of the present invention,
the evaluation device allows for the distance between the
measuring device and the at least one object and/or the speed
difference between the measuring device and the at least one
object to be determined as a function of the measured
20 frequencies of the first mixed signal and of the measured
frequencies of the second mixed signal.

In another advantageous refinement of the present invention,
the evaluation device allows for the difference between the
25 absolute phase of the first mixed signal and the absolute
phase of the second mixed signal to be determined.

In another advantageous refinement of the present invention,
the evaluation device allows for the distance between the
30 measuring device and the at least one object and/or the speed
difference between the measuring device and the at least one
object to be determined as a function of the difference
between the phase of the first mixed signal and the phase of
the second mixed signal.

In another advantageous refinement of the present invention, the emitting device and the receiving device are each an antenna. The emitting device and the receiving device, however, may also be implemented by a common antenna.

5 In another advantageous refinement of the present invention, the emitting device is an optical element, in particular a laser. In another advantageous refinement of the present invention, the receiving device in this instance is a light-sensitive element, in particular a photoelement or a photodiode, which is suited for measuring the phase of the reflected laser light.

10 The above-mentioned objective is furthermore achieved by a method for measuring a distance between an emitting device and at least one object and/or for measuring a speed difference between the emitting device and the at least one object, a transmission signal having at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions being sent by the emitting device, at least two signal portions of a signal portion sequence differing in their frequency in each case by a non-constant differential frequency. The differential frequency of the 15 first signal portion sequence may differ from the differential frequency of the second signal portion sequence, in particular by at least 5%, advantageously by at least 10%.

20 In another advantageous refinement of the present invention, a reflection signal of the transmission signal reflected by the at least one object is received, advantageously the first signal portion sequence is mixed with a portion of the first signal portion sequence reflected by the at least one object to form a first mixed signal, and advantageously the

dominating (measured) frequencies of the first mixed signal are ascertained.

In another advantageous refinement of the present invention,

5 the distance between the emitting device and the at least one object and/or the speed difference between the emitting device and the at least one object is determined as a function of the dominating frequencies of the first mixed signal.

10 In another advantageous refinement of the present invention, the second signal portion sequence is mixed with a portion of the second signal portion sequence reflected by the at least one object to form a second mixed signal, and in another advantageous refinement of the present invention, the 15 dominating frequencies of the second mixed signal are ascertained.

In another advantageous refinement of the present invention, the distance between the emitting device and the at least one 20 object and/or the speed difference between the emitting device and the at least one object is determined as a function of the dominating frequencies of the first mixed signal and of the dominating frequencies of the second mixed signal.

25 In another advantageous refinement of the present invention, the difference between the phase of the first mixed signal and the phase of the second mixed signal is determined, and in another advantageous refinement of the present invention, the distance between the emitting device and the at least one 30 object and/or the speed difference between the emitting device and the at least one object is determined as a function of the differences between the phases of the first mixed signal and the phases of the second mixed signal.

A motor vehicle in the sense of the present invention is in particular a land vehicle that may be used individually in road traffic. In particular, motor vehicles in the sense of the present invention are not restricted to land vehicles
5 having an internal combustion engine.

Further advantages and details are derived from the following description of exemplary embodiments. The figures show:

10 Fig. 1 a front view of a motor vehicle;

Fig. 2 a side view of a motor vehicle;

Fig. 3 an exemplary embodiment of a radar device;

15 Fig. 4 an exemplary embodiment of a frequency-time diagram
and

Fig. 5 an exemplary embodiment of an optical measuring
20 device.

Fig. 1 and Fig. 2 show a motor vehicle 1 in an exemplary embodiment. Fig. 1 shows a front view of motor vehicle 1, and Fig. 2 shows a side view of motor vehicle 1. Motor vehicle 1 has a front bumper 2 and a rear bumper 3. In the exemplary embodiment, front bumper 2 has distance and/or speed sensors
25 10, 11, 12, 13, 14, 15, 16 for measuring a distance R between motor vehicle 1 and at least one object or obstacle 20 such as another motor vehicle, for example, and/or for measuring a
30 speed difference v between motor vehicle 1 and the at least one object or obstacle 20, speed difference v being the difference between the speed vH of obstacle 20 and the speed vF of motor vehicle 1.

Depending on the application of distance and/or speed sensors 10, 11, 12, 13, 14, 15, 16, more or fewer distance and/or speed sensors may be situated on bumper 2. This means that it is also possible that only one sensor is used. Alternatively 5 or additionally, distance and/or speed sensors may also be situated on rear bumper 3, on side mirrors 4, 5, on side doors 6, 7, on A, B, C pillars and/or on a hatchback 8. The distance and/or speed sensors may be oriented in different directions and/or at different levels. Examples of the 10 application of such distance and/or speed sensors can be gathered from the dissertation "Radar Systems for the Automatic Distance Control in Automobiles" by R. Mende, Technical University Carolo-Wilhelmina, Braunschweig, 1999.

15 Fig. 3 shows a radar device 30, which is usable as a distance and/or speed sensor 10, 11, 12, 13, 14, 15, 16, for example. Radar device 30 has a radar sensor 40 and an evaluation device 41. Radar device 30 has an oscillator or a signal generator 31 for producing a transmission signal $s(t)$, a transmitting 20 antenna 35 for emitting the transmission signal $s(t)$ and a receiving antenna 36 for receiving a reflection signal $r(t)$ of the emitted transmission signal $s(t)$ reflected by an object such as obstacle 20. t indicates time in this context.

25 Transmission signal $s(t)$ produced by signal generator 31 includes at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions, the at least two signal portions of a signal portion sequence 30 differing in their frequency in each case by one differential frequency, and the differential frequency of the first signal portion sequence differing from the differential frequency of the second signal portion sequence, in particular by at least 5%, advantageously by at least 10%. An exemplary embodiment

of such a transmission signal is shown in Fig. 4 in a frequency-time diagram.

In this context, A₁, A₂, A₃, ... indicate the signal portions 5 of a first signal portion sequence A(t) and B₁, B₂, B₃, ... indicate the signal portions of a second signal portion sequence B(t). Such signal portions are also called chirps. In the present exemplary embodiment, the time durations T_{Burst} for signal portions A₁, A₂, A₃, ... and B₁, B₂, B₃, ... are of 10 equal length. Time duration T_{Burst} of signal portions A₁, A₂, A₃, ... is represented in Fig. 4 by a solid line and time duration T_{Burst} of signal portions B₁, B₂, B₃, ... is represented by a dashed line.

15 The frequency within a signal portion A₁, A₂, A₃, ... or B₁, B₂, B₃, ... may be a constant carrier frequency f_T(t), but it may also be a constant carrier frequency f_T(t) modulated by a modulation frequency.

20 The individual signal portions A₁, A₂, A₃, ... of first signal portion sequence A(t) differ in their frequency or their carrier frequency f_T(t) in each case by a differential frequency f_{Hub,A}/ (N-1), f_{Hub,A} being the difference between the carrier frequency of first signal portion A₁ of first signal portion sequence A(t) and the carrier frequency of the Nth signal portion of the first signal portion sequence A(t), and N being the number of signal portions A₁, A₂, A₃, ... of first signal portion sequence A(t). The individual signal portions 25 B₁, B₂, B₃, ... of first signal portion sequence B(t) differ in their frequency or their carrier frequency f_T(t) in each case by a differential frequency f_{Hub,B}/ (N-1), f_{Hub,B} being the difference between the carrier frequency of first signal portion B₁ of second signal portion sequence B(t) and the carrier frequency of the Nth signal portion of the second signal portion sequence B(t), and N likewise being the number 30 35

of signal portions B1, B2, B3, ... of first signal portion sequence B(t). Surprisingly, it proved to be especially advantageous to choose the differential frequency $f_{Hub,A}/(N-1)$ of the first signal portion sequence A(t) to differ from the differential frequency $f_{Hub,B}/(N-1)$ of the second signal portion sequence B(t) in particular by at least 5%, advantageously by at least 10%.

Additionally, a frequency shift f_{Shift} may be provided between signal portion A1 of first signal portion sequence A(t) and signal portion B1 of second signal portion sequence B(t).

Accordingly, first signal portion sequence A(t) results in

$$A(t) = \sum_{n=0}^{N-1} \cos\left(2\pi \cdot \left(f_{TA1} + \frac{n}{N-1} \cdot f_{Hub,A}\right) \cdot t\right) \cdot \text{rect}\left(\frac{t}{T_{Burst}} - \frac{1}{2} - 2n\right)$$

15

and the second signal portion sequence B(t) in

$$B(t) = \sum_{n=0}^{N-1} \cos\left(2\pi \cdot \left(f_{TA1} + f_{Shift} + \frac{n}{N-1} \cdot f_{Hub,B}\right) \cdot t\right) \cdot \text{rect}\left(\frac{t}{T_{Burst}} - \frac{1}{2} - (2n+1)\right)$$

where f_{TA1} refers to the carrier frequency of signal portion A1
20 and rect refers to the rectangle function.

The transmission signal s(t) thus results in

$$s(t) = A(t) + B(t)$$

25

Via a coupler 32, transmission signal s(t) is supplied to a mixer 38 for mixing transmission signal s(t) and reflection signal r(t). Mixer 38 outputs an inphase signal I(t).

30 Via another coupler 33, transmission signal s(t) is additionally supplied to a phase shifter 37, which shifts the phase of transmission signal s(t) with respect to the carrier

frequency by 90° , that is, by $\pi/2$. The phase-shifted transmission signal is supplied to a mixer 39 for mixing the phase-shifted transmission signal and the reflection signal $r(t)$, which is supplied to mixer 39 via a coupler 34. Mixer 5 39 outputs a quadrature signal $Q(t)$.

Inphase signal $I(t)$ and quadrature signal $Q(t)$ are mixed signals in the sense of the claims.

10 Radar device 30 has a multiplicator 42, which is used to multiply quadrature signal $Q(t)$ by the complex number j to yield $jQ(t)$. $I(t)$ and $jQ(t)$ are added to form a complex mixed signal $m(t)$. Complex mixed signal $m(t)$ is likewise a mixed signal in the sense of the claims. Radar device 30
15 additionally has a frequency analyzer 43, which is used to form a spectrum $M(\kappa)$ of complex mixed signal $m(t)$ over frequency κ . Using a detector 44, the dominating frequency κ_A of mixed signal $m(t)$ is ascertained with respect to first signal sequence $A(t)$, and the dominating frequency κ_B of mixed
20 signal $m(t)$ is ascertained with respect to second signal sequence $B(t)$.

In this instance, the processing of the individual signal sequences $A(t)$ and $B(t)$ advantageously occurs separately by
25 temporal separation such that with the aid of mixers 38 and 39 first signal portion sequence $A(t)$ is mixed with a portion of first signal portion sequence $A(t)$ (of reflection signal $r(t)$) reflected by the at least one object 20 to form a first mixed signal $I_A(t)$, $Q_A(t)$ or $m_A(t)$, and second signal portion sequence $B(t)$ is mixed with a portion of second signal portion sequence $B(t)$ (of reflection signal $r(t)$) reflected by the at least one object 20 to form a second mixed signal $I_B(t)$, $Q_B(t)$ or $m_B(t)$. For this purpose, frequency analyzer 43 forms a complex spectrum $M_A(\kappa)$ of complex mixed signal $m_A(t)$ over frequency κ and a complex spectrum $M_B(\kappa)$ of complex mixed
35

signal $m_B(t)$ over frequency κ . Using detector 44, frequencies κ_A of complex mixed signal $m_A(t)$ (that is, with respect to first signal sequence $A(t)$) and the frequencies κ_B of complex mixed signal $m_B(t)$ (that is, with respect to second signal sequence $B(t)$) are ascertained.

Radar device 30 has an evaluator 45 for determining the distance R and/or the differential speed v . For this purpose, evaluator 45 solves the following system of equations:

10

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

where c is the speed of light.

15 In addition there may be a provision for detector 44 also to ascertain the difference $\Delta\psi$ between the phase of complex mixed signal $m_A(t)$ and the phase of complex mixed signal $m_B(t)$. In this case -- for determining distance R and/or speed difference v -- evaluator 45 may be used to solve the
20 following overdetermined system of equations, e.g. by a least square algorithm:

$$\Delta\psi = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + \frac{2R \cdot f_{Shift}}{c} \right)$$

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

There may be an additional provision to use more than two signal portion sequences. Thus, for example, three signal portion sequences A(t), B(t) und C(t) of different differential frequency $f_{Hub,A}/(N-1)$, $f_{Hub,B}/(N-1)$ and $f_{Hub,C}/(N-1)$ 5 may be used and suitably emitted and processed. In this case -- for determining distance R and/or speed difference v -- evaluator 45 may be used to solve, for example, the following overdetermined system of equations, for example, by a least square algorithm:

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

10

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

$$\kappa_C = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,C}$$

15

$$\Delta\psi_{AB} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,B} - f_{T,A}}{c} \right) \text{ where } f_{T,B} - f_{T,A} = f_{Shift,BA}$$

$$\Delta\psi_{AC} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,C} - f_{T,A}}{c} \right) \text{ where } f_{T,C} - f_{T,A} = f_{Shift,CA}$$

20 Accordingly there may be a provision to use, appropriately emit and process, for example, four signal portion sequences A(t), B(t), C(t) and D(t) of different differential frequency $f_{Hub,A}/(N-1)$, $f_{Hub,B}/(N-1)$, $f_{Hub,C}/(N-1)$ and $f_{Hub,D}/(N-1)$. In this case -- for determining distance R and/or speed difference v -- evaluator 45 may be used to solve, for example, the following overdetermined system of equations, for example, by a least square algorithm:

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N - 1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

$$\kappa_C = \frac{2v \cdot f_r}{c} \cdot (N - 1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,C}$$

$$\kappa_D = \frac{2v \cdot f_T}{\epsilon} \cdot (N - 1) \cdot T_{Burst} - \frac{2R}{\epsilon} \cdot f_{Hub,D}$$

$\Delta\psi_{AB}$ = see above

5 $\Delta\psi_{AC}$ = see above

$$\Delta\psi_{AD} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,D} - f_{T,A}}{c} \right) \text{ where } f_{T,D} - f_{T,A} = f_{Shift,DA}$$

In addition, a different time duration may be provided for the signal portions of different signal sequences.

10

Fig. 5 shows an exemplary embodiment for an optical measuring device 50 for the improved measurement of speed difference v or distance R . Optical measuring device 50 has an optical sensor 60 and an evaluation device 61, which corresponds essentially to evaluation device 41. Optical measuring device 50 has an oscillator or a signal generator 51 for producing a transmission signal $s_1(t)$, a laser 55 for emitting light at the frequency of transmission signal $s_1(t)$ and a photoelement 56 for receiving a light reflected by at least one object such as obstacle 20 and for producing a reflection signal $r_1(t)$ at a frequency corresponding to the frequency of the reflected light. The transmission signal $s_1(t)$ produced by signal generator 51 corresponds to transmission signal $s(t)$, but is

located in another frequency range. Via a coupler 52, transmission signal $s_1(t)$ is supplied to a mixer 58 for mixing transmission signal $s_1(t)$ and reflection signal $r_1(t)$. Mixer 58 outputs an inphase signal $I(t)$.

Via another coupler 53, transmission signal $s_1(t)$ is additionally supplied to a phase shifter 57, which shifts the phase of transmission signal $s_1(t)$ with respect to the carrier frequency by 90° , that is, by $\pi/2$. The phase-shifted transmission signal is supplied to a mixer 59 for mixing the phase-shifted transmission signal and the reflection signal $r_1(t)$, which is supplied to mixer 59 via a coupler 54. Mixer 59 outputs a quadrature signal $Q(t)$.

The elements, signals and frequency ranges in the figures are drawn with simplicity and clarity in mind and not necessarily to exact scale. Thus, for example, the orders of magnitude of some elements, signals or frequency ranges are exaggerated in order to facilitate understanding of the exemplary embodiments of the present invention.

List of Reference Symbols:

1	motor vehicle
2, 3	bumper
4, 5	side mirror
5 6, 7	side door
8	hatchback
10, 14, 15, 16	distance and/or speed sensor
20	object or obstacle
30	radar device
10 51	signal generator
33, 34, 52,	
53, 54	coupler
35	transmitting antenna
36	receiving antenna
15 57	phase shifter
39, 58, 89	mixer
40	radar device
41, 61	evaluation device
42	multiplier
20 43	frequency analyzer
44	detector
45	evaluator
50	optical measuring device
55	laser
25 56	photoelement
60	optical sensor
A, B	signal sequence
A1, A2, A3, B1,	
B2, B3	signal portion
30 $f_{Hub,A}$, $f_{Hub,B}$	difference between the carrier frequency of the first signal portion of a signal portion sequence and the carrier frequency of the last signal portion of the signal portion sequence
35 f_{shift}	frequency shift

$f_T(t)$	carrier frequency
$I(t)$	inphase signal
$m(t)$	complex mixed signal
$M(\kappa)$	complex spectrum
5 $Q(t)$	quadrature signal
R	distance
$r(t), r_l(t)$	reflection signal
$s(t), s_l(t)$	transmission signal
t	time
10 T_{Burst}	time duration
v	speed difference
v_F	speed of the motor vehicle
v_H	speed of the obstacle
$\Delta\psi$	difference in the phase of two mixed signals
15 κ	frequency
κ_A, κ_B	measured frequency of a complex mixed signal